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TESTS OF TWO MODELS REPRESENTING INTERMEDIATE INBOARD AND OUTBOARD WING SECTIONS OF THE XB-36 AIRPLANE

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MEMORANDUM REPORT

for the

Army Air Forces, Materiel Command

TESTS OF TWO MODELS REPRESENTING INTERMEDIATE INBOARD AND OUTBOARD WING SECTIONS OF THE XB-36 AIRPLANE

By Seymour M. Bogdonoff

INTRODUCTION

At the request of the Army Air Forces, Materiel Command, tests were made in the two-dimensional low-turbulence pressure tunnel and the two-dimensional low-turbulence tunnel of two models submitted by the Consolidated Aircraft Corporation.

The model representing the inboard section was tested with four combinations of flap shape and slot entry to obtain the best slotted flap characteristics on the basis of maximum section lift coefficient and minimum section drag coefficient when retracted. The combination chosen was then tested to determine the effect of varying the gap with flap in the maximum lift position. Tests on this section included lift, drag, pressure-distribution measurements, and pitching moments for various flap deflections δ_f. A scale-effect test was made on the section with flap retracted and at maximum lift position.

Tests on the model representing the outboard section, an airfoil with an internally balanced aileron and balanced split flap, included lift, pressure-distribution measurements, and pitching moments with various aileron deflections δ_a for each flap deflection. Drag and scale-effect data were obtained for the flap-retracted and neutral-aileron condition. Aileron effectiveness was also included.

Most of the data were obtained at a Reynolds number R of approximately 8,000,000 and 9,000,000 with the exception of the pitching-moment data obtained on the moment balance. These tests were run at a Reynolds number of approximately 2,000,000. The large number of pressure-distribution diagrams obtained are not presented in this report but are available.

MODELS

The models were of 24-inch chord and constructed of wood with metal flaps and aileron. The wings, flaps, and aileron all had pressure-distribution orifices. The sections tested were intermediate sections of the actual wing which had as a root section an NACA 63(420)-422 airfoil and as a tip section an NACA 63(420)-517 airfoil. The intermediate inboard and outboard section models were approximately an NACA 63(420)-421.35 airfoil and an NACA 63(420)-520.6 airfoil.

The inboard section had a 24.3-percent-chord slotted flap. Four combinations of flap shape and slot entry were interchangeable on this model.

The outboard section had an internally balanced 12.5-percent-chord aileron and a 16.0-percent-chord balanced split flap which retracted into the lower surface of the airfoil just ahead of the aileron.

METHODS[1]

Section drag coefficients were obtained by the wake-survey method using an integrating manometer. Section lift coefficients were obtained by measuring the lift reaction on the floor and ceiling of the tunnel by means of integrating manometers connected to pressure orifices in the floor and ceiling. Pressure-distribution data were obtained by reading and plotting the pressures directly from a multiple-tube manometer.

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[1]At the time this report was originally published, some of the corrections required for reducing the test data to free-air conditions had not been determined. The values of section lift coefficient c_l for the inboard wing section should be corrected by the equation

$$c_{l(\text{corrected})} = 0.965c_l + 0.036c_{l_{\alpha=1^\circ}}$$

where $c_{l_{\alpha=1^\circ}}$ is the section lift coefficient at an angle of attack of 1°.

The section lift coefficients for the outboard wing section should be corrected by the equation

$$c_{l(\text{corrected})} = 0.965c_l + 0.037c_{l_{\alpha=1^\circ}}$$

The section pitching-moment coefficients presented for the outboard section were obtained from a moment balance using a calibrated torque rod. The model was pivoted at the quarter-chord point and there was a gap of approximately 0.15 inch between the model ends and the tunnel walls to allow free movement of the model. All tests of this type were made at a Reynolds number of approximately 2,000,000.

For the inboard section, pitching moments were obtained by the above method for flap deflections of 0° and 20°. For a flap deflection of 40°, however, where section pitching moments were above those for which the balance was designed and oscillations were large, moments were calculated by graphical means from pressure-distribution data obtained at a Reynolds number of approximately 8,000,000. These calculations were repeated for a flap deflection of 20° to check the data obtained from the moment balance and to give an indication of possible scale effect on section pitching-moment coefficient. The graphical method used gives the total section pitching-moment coefficient and includes the component of moment associated with the chord force.

RESULTS AND DISCUSSION

Inboard section.- The inboard section model with a slotted flap was equipped to be tested with four combinations of flap shape and slot entry (fig. 1). The lift data obtained using the smallest flap gap, A-A', are presented in figures 2 to 5 and the curve of section drag coefficient c_d against section lift coefficient c_l for flap retracted is presented in figure 6. Some trouble was experienced in getting accurate drag measurements because of spanwise flow in the slot, although all drag tests were made with thin cardboard dams glued in the slot. Also included in figure 6 are the results of a test using flap 2 and nose 2 with the gap filled with modeling clay.

No combination of flap and nose gives any particularly large advantage over any of the other combinations, but flap 1 and nose 1 seem to be the most favorable combination since it has the highest maximum lift coefficient, 3.10, with a smooth lift curve, and slightly lower drag over most of the low-drag range. The maximum lift coefficient was obtained at a flap deflection of 40°. Lift data were also obtained for a flap deflection of 20° and are presented in figure 7.

On the basis of the tests made with the slot open and then filled with modeling clay, the need of a door to close the slot when the flap is retracted is not indicated.

Two alternate flap positions were tested (fig. 8) with the flap deflected 40° to study the effect of varying the gap. The results are presented in figure 9. The maximum lift coefficient increased from 3.10 for the smallest gap, A-A', to 3.28 for the largest gap tests, C-C'.

With the flap in the 40° C-C' position, lift data were obtained at Reynolds numbers of 2,000,000, 3,000,000 6,000,000, and 9,000,000. Over this range the maximum section lift coefficient increased from 3.06 to 3.28 (fig. 10).

Moment data for the flap retracted, 20° deflection, and 40° C-C' deflection, are presented in figure 11 and are of a magnitude expected for a 0.25c slotted flap. For the flap retracted and at 20° deflection, section pitching-moment coefficients were obtained from moment-balance data. For the 40° C-C' deflection, and as a check on the 20° deflection, section pitching-moment coefficients were calculated from pressure-distribution data. The agreement between the moment balance and pressure-distribution data is considered very satisfactory and the scale effect on section pitching-moment coefficient may be considered negligible below maximum lift in the range tested.

Outboard section.- For the outboard section model with the internally balanced aileron and balanced split flap (fig. 12) lift data were obtained for six positions of flap through a range of aileron deflections (figs. 13 to 18). For the flap retracted and fully deflected, 50°, lift data were obtained for aileron deflections of from 20° to -20° in

5° increments. For the intermediate positions, 10°, 20°, 30°, and 40°, lift data were obtained only at 20°, 0°, and -20° deflections of the aileron. The maximum section lift coefficient obtained for neutral aileron was 2.57 for 50° deflection. The maximum lift coefficient obtainable was 2.59 with the flap at 50° and the aileron at 5°. For further positive deflection of the aileron with the flap fully deflected, the maximum section lift coefficient falls off to 2.4 for 20° deflection.

For all of the intermediate flap positions there seems to be a definite tendency to have higher maximum lift coefficients with negative aileron deflections. The maximum lift coefficients for flap deflections of 20° and 30° are higher for -20° deflection of the aileron than for 0° or 20°. A negative deflection of the aileron probably induces a lower pressure behind the flap causing larger and better flow through the gap and around the flap. This effect disappears at 40° and 50° although the tendency is still shown by the wide flat top of the lift curve for 40° flap deflection (position 5) and -20° aileron deflection (fig. 17).

The effect of a deflected flap or aileron may be measured as a change of angle of attack of the wing section or by the change in the zero-lift angle. A factor of proportionality $\left(\text{denoted by } \Delta\alpha/\Delta\delta_{c_l=0.0}\right)$ may be taken as a measure of aileron effectiveness, although the airplane does not actually fly in this condition. This factor $\Delta\alpha/\Delta\delta$ equals 0.34 for the flap retracted and falls in the normal aileron-effectiveness range. From figure 13 it may be seen that this factor stays constant to high section lift coefficients. For the flap fully extended to 50°, $\Delta\alpha/\Delta\delta$ drops to 0.26 which is below the normal range and gives only 76.5 percent of the aileron effectiveness obtained with the flap retracted. At high section lift coefficients the aileron effectiveness drops off still further, giving only about 60 percent of the effectiveness obtained with flap retracted.

For the intermediate flap deflections, positions 2, 3, and 4, aileron effectiveness drops to a critical point, as low as 37 percent of normal effectiveness for position 4 in the high lift condition. For these three positions the average $\Delta\alpha/\Delta\delta$ is approximately one-half of the normal aileron effectiveness, and cannot give effective lateral control in this condition. Other investigations show that moving the flap farther back and allowing a large gap between flap and aileron will give almost full aileron effectiveness at maximum flap deflections. Better effectiveness at intermediate flap positions may also be obtained.

The variation of maximum section lift coefficient for flap retracted and fully deflected, 50°, for change in Reynolds number is presented in figures 19 and 20. For flap retracted, the maximum lift coefficient varies from 1.28 to 1.47 for a change in Reynolds number of from 2,000,000 to 8,000,000; for 50° deflection of the flap, the maximum lift coefficient varies from 2.40 to 2.68 for the same change in Reynolds number.

In figure 21 is presented the curve of section drag coefficient against section lift coefficient for the flap-retracted and aileron-neutral condition.

Section pitching-moment data for all flap deflections through a range of aileron deflections are presented in figures 22 to 27 and are of a magnitude expected for such an arrangement. These data were obtained from moment-balance measurements. The data at or beyond maximum lift are not considered reliable because there were gaps between the tunnel walls and the model ends. The effect of gap and Reynolds number may be seen in figure 11 for 20° deflection of the slotted flap. Below maximum lift the effects may be considered negligible.

CONCLUSIONS

Inboard Section

1. Flap 1 and slot entry 1 seem to be the best of the combinations tested.

2. A maximum section lift coefficient of 3.28 was obtained with the largest flap gap tested, C-C', at a flap deflection of 40°. This compares very well with other tests of similar flaps.

3. On the basis of the tests made, the need of a door to close the slot when the flap is retracted in some configurations is not definitely indicated.

Outboard Section

4. The maximum section lift coefficient obtained was 2.59 for 50° deflection of the flap and 5° deflection of the aileron.

5. Some account must be taken of the increase in maximum section lift coefficient for negative aileron deflections for intermediate flap positions 2, 3, and 4.

6. Aileron effectiveness is deficient for the intermediate flap positions and falls slightly below the range usually considered acceptable for the fully deflected position. The effectiveness of the aileron alone, flap retracted, is satisfactory.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., January 7, 1943.

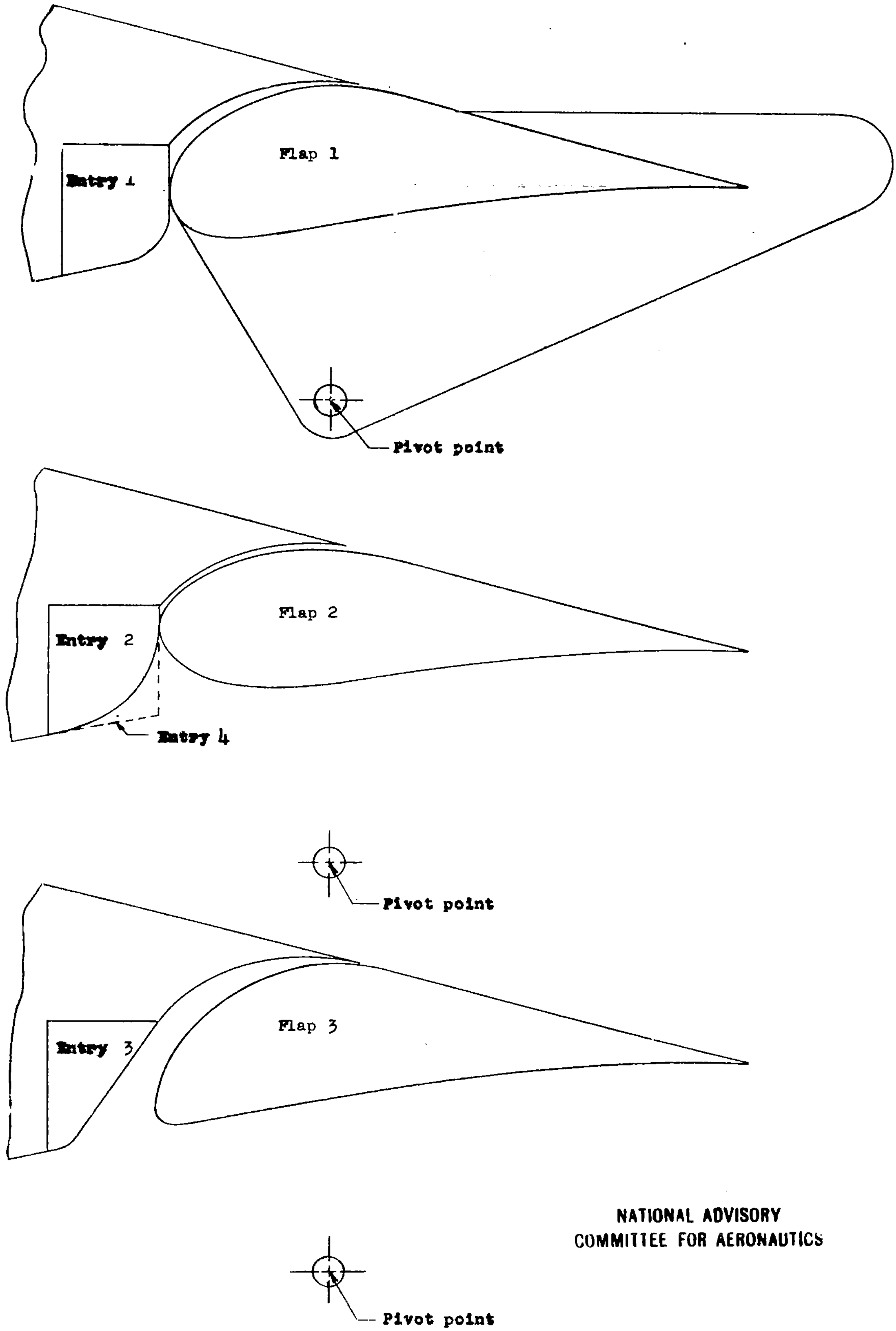

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Figure 1.- Combination of flap and slot entry for inboard wing section model of XB-36 airplane with slotted flap.

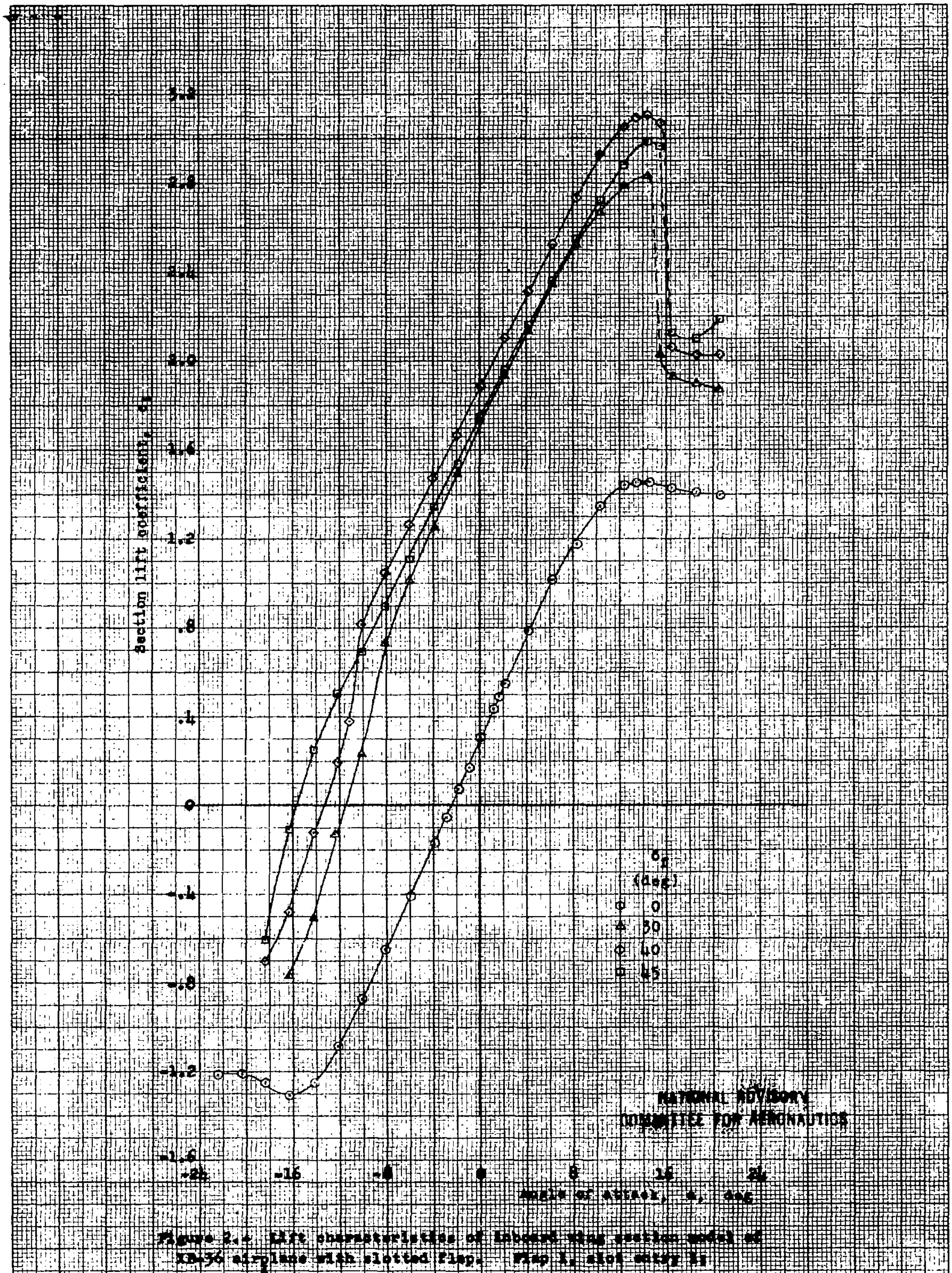

Figure 2.- Lift characteristics of inboard wing section model of XB-36 airplane with slotted flap. Flap 1, slot entry 1; R, 9 × 10^6.

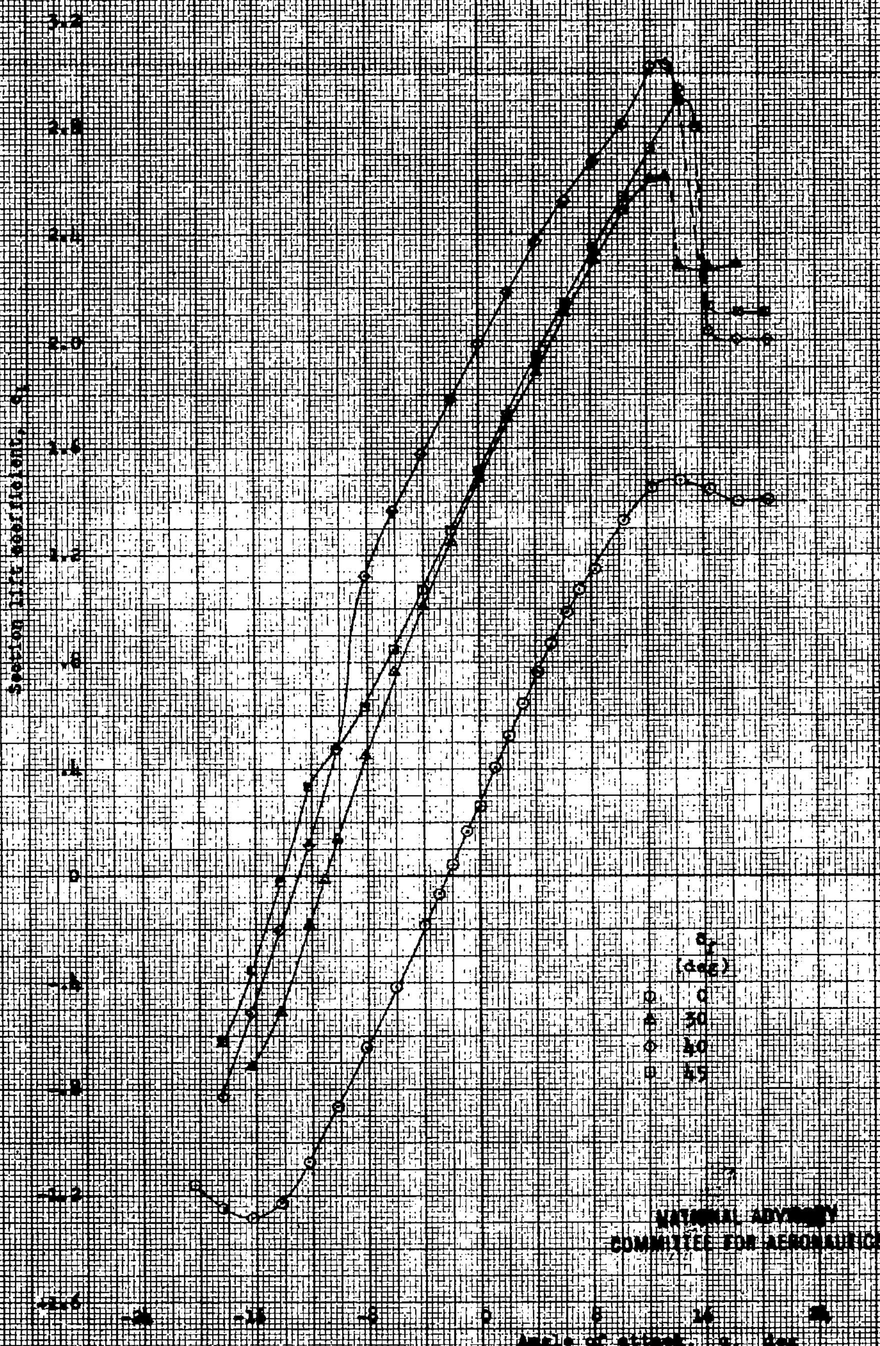

Figure 3.- Lift characteristics of inboard wing section model of XB-36 airplane with slotted flap. Flap 2, slot entry 2; R, 9 × 10^6.

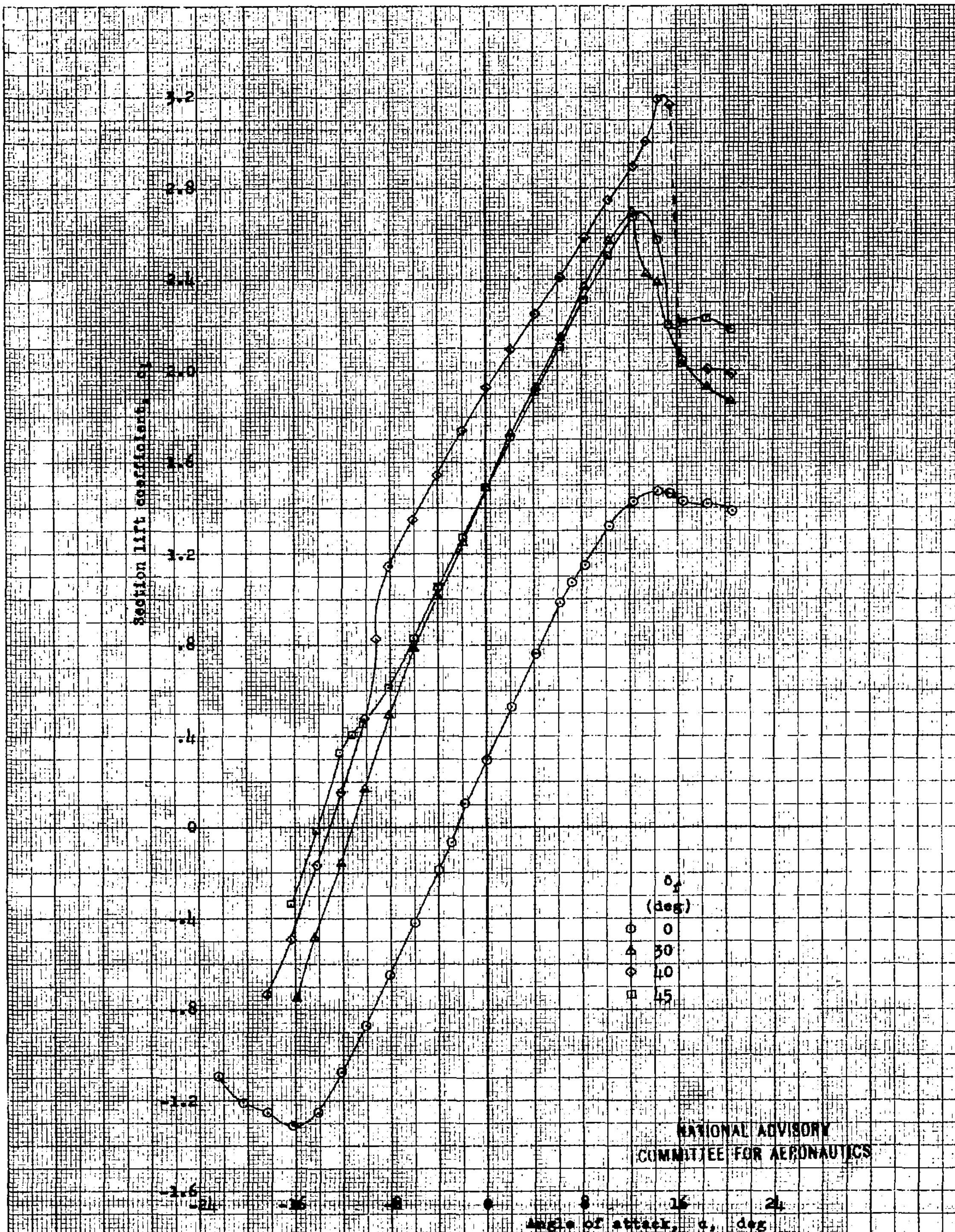

Figure 4.- Lift characteristics of inboard wing section model of XB-36 airplane with slotted flap. Flap 2, slot entry 4; R, 9 × 10^6.

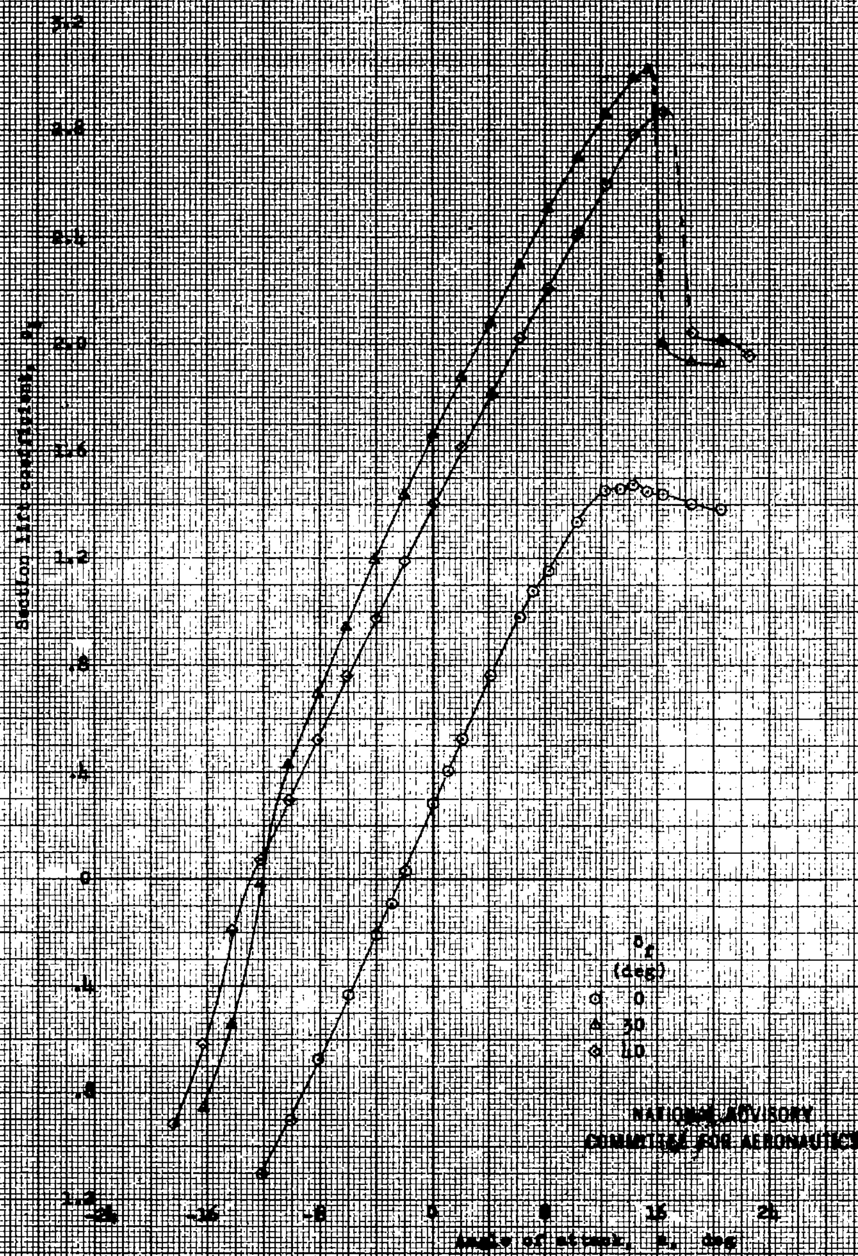

Figure 5.- Lift characteristics of inboard wing section model of XB-36 airplane with slotted flaps. Flap 3, slot entry 5; R, 9×10^6.

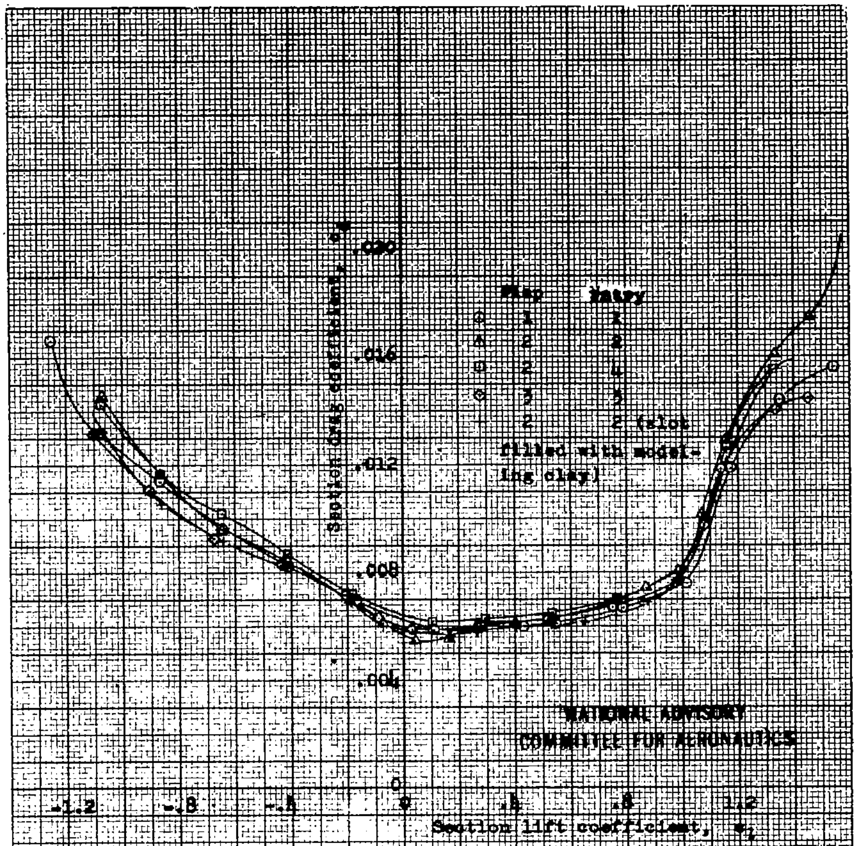

Figure 6.- Drag characteristics of inboard wing section model of XB-36 airplane with flap retracted. Four combinations of flap and slot entry compared with basic wing (slot filled with modeling clay). R, 9×10^6.

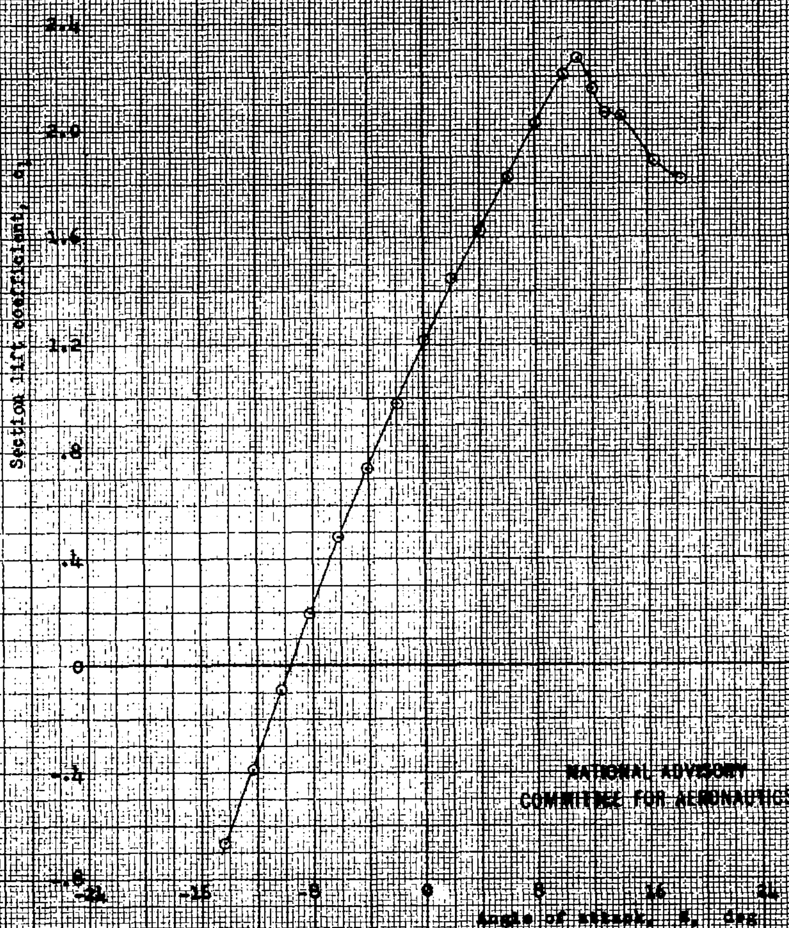

Figure 7a.- Lift characteristics of inboard wing section model of XB-36 airplane with slotted flap. Flap 1, slot entry 1; δ_f, 20°; R, 9×10^6.

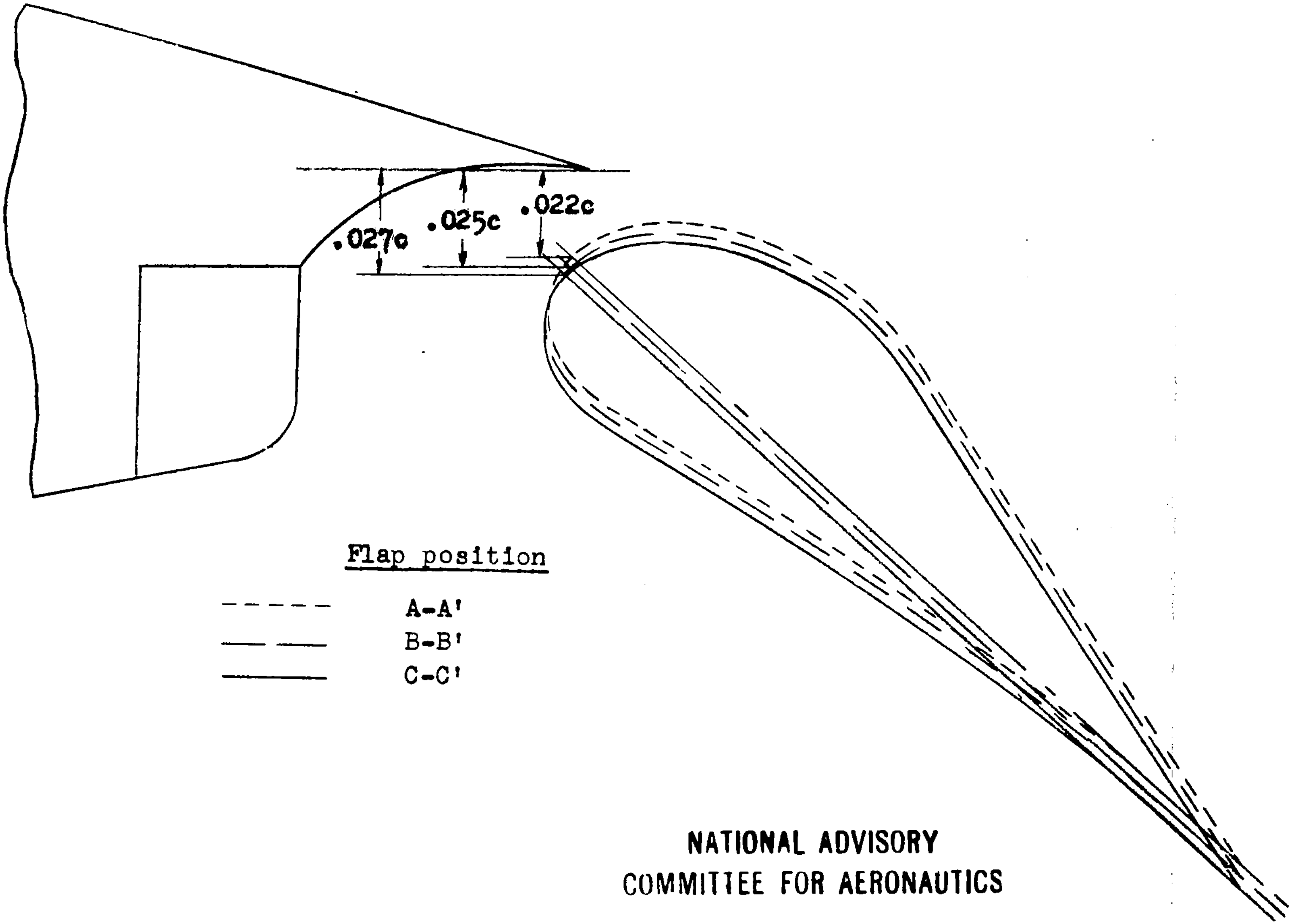

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Figure 8.- Three positions of slotted flap on inboard wing section model of XB-36 airplane used to test effect of varying gap size. Flap 1, slot entry 1; δ_f, 40°.

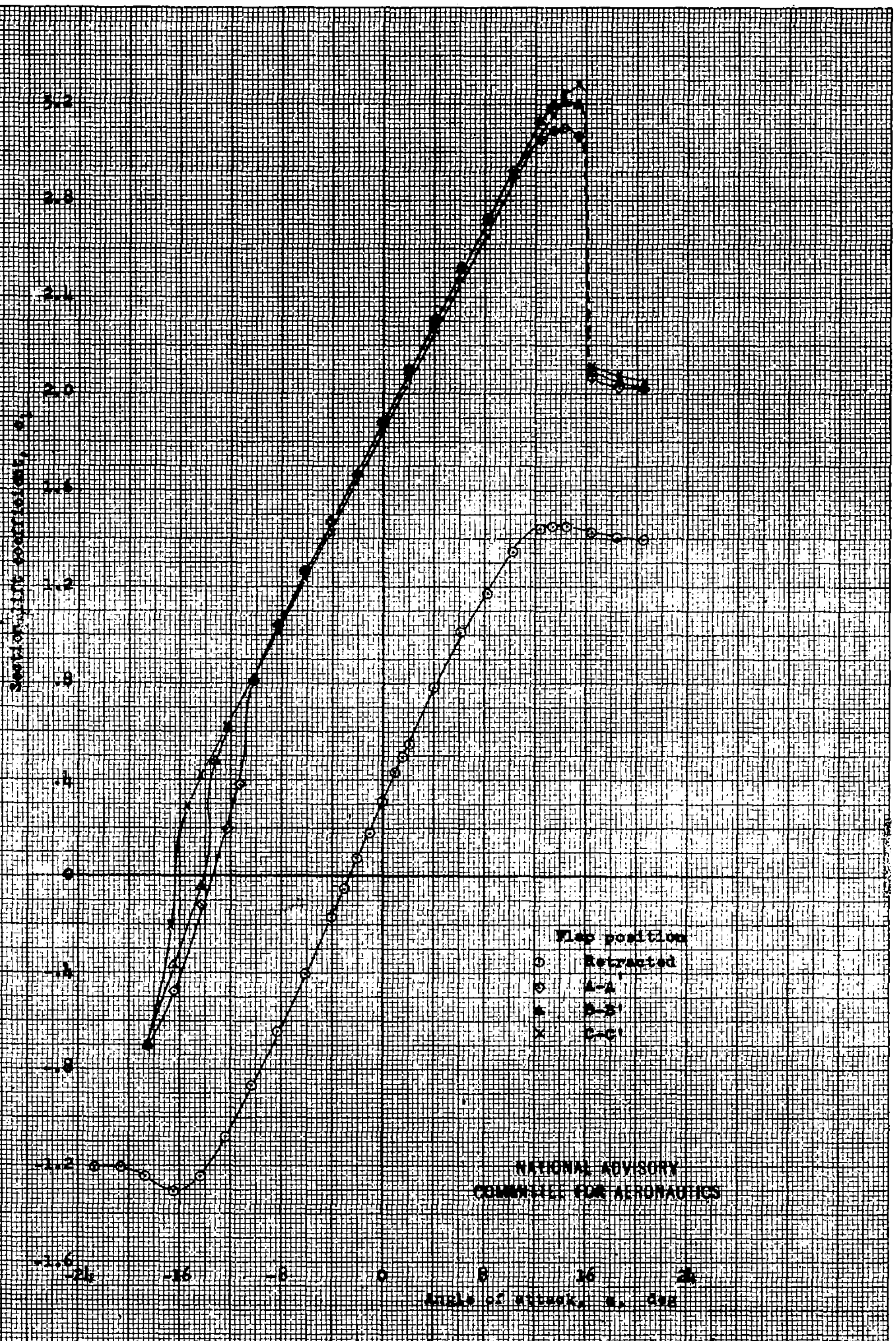

Figure 9.- Lift characteristics of inboard wing section of XB-36 airplane, slotted flap with gaps of three sizes. Flap 1, slot entry 1; δ_f, 40°; R, 9×10^6.

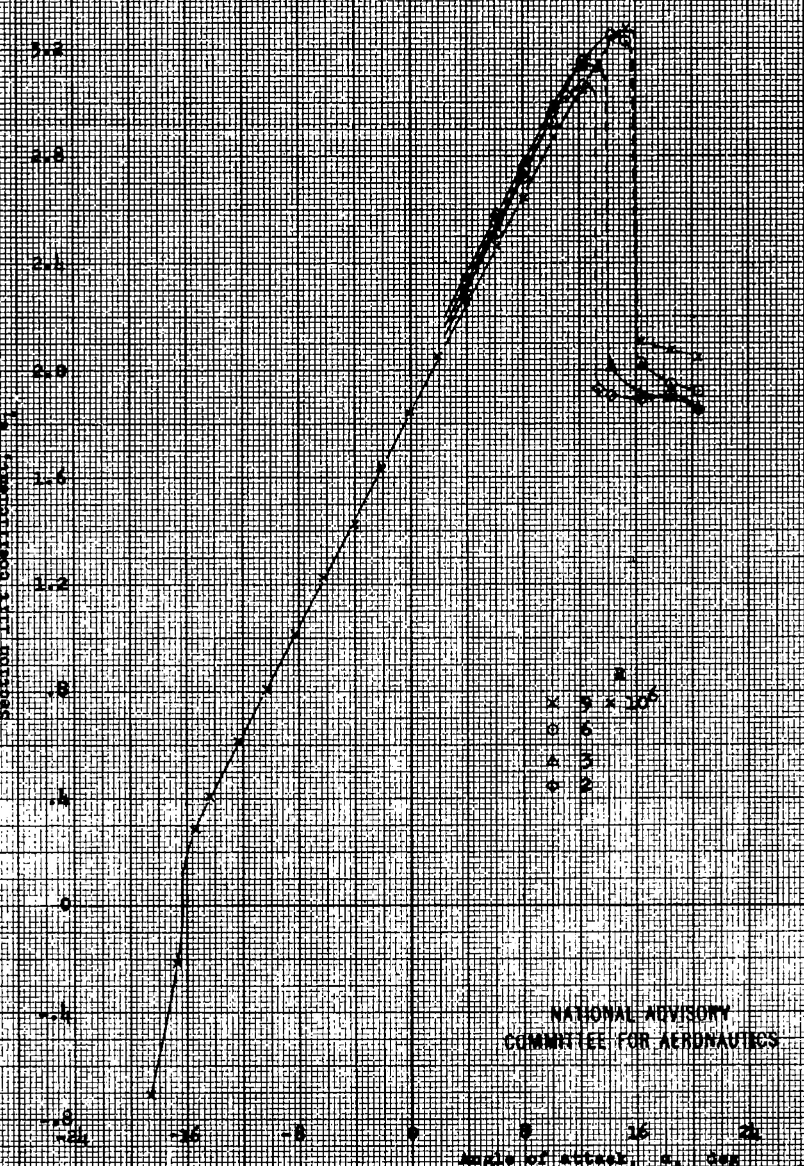

Figure 10.- Lift characteristics of inboard wing section model of XB-36 airplane with slotted flap at four Reynolds numbers. Flap 1, slot entry 1; δ_f, 40°; flap position B-0'.

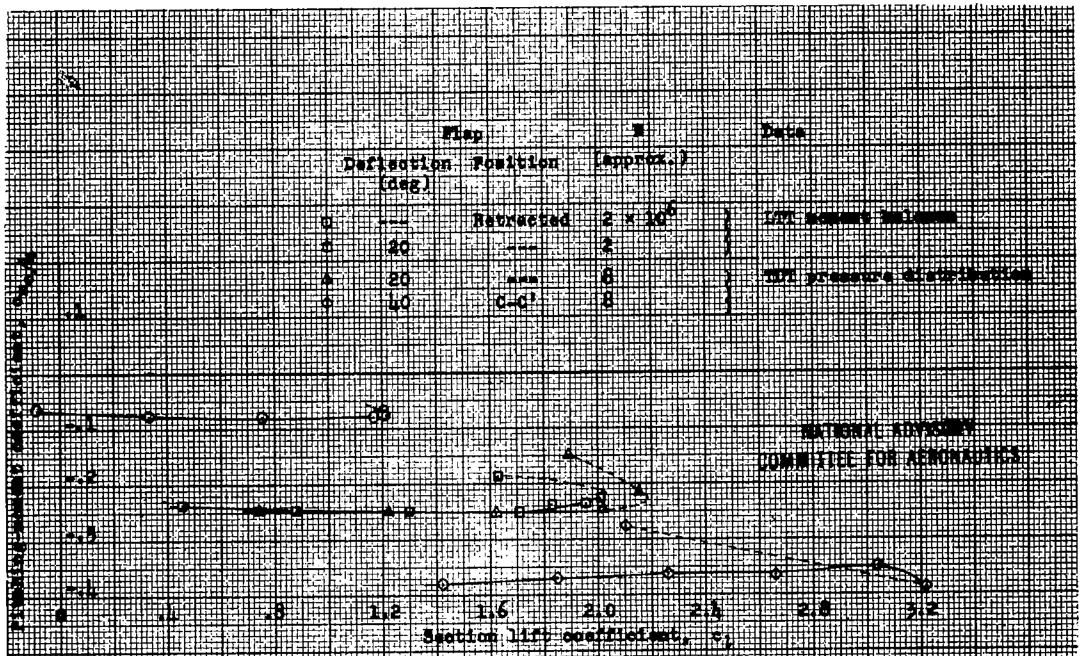

Figure 11.- Pitching-moment characteristics of inboard wing section model of XB-36 airplane with three deflections of slotted flap. Flap 1, slot entry 1.

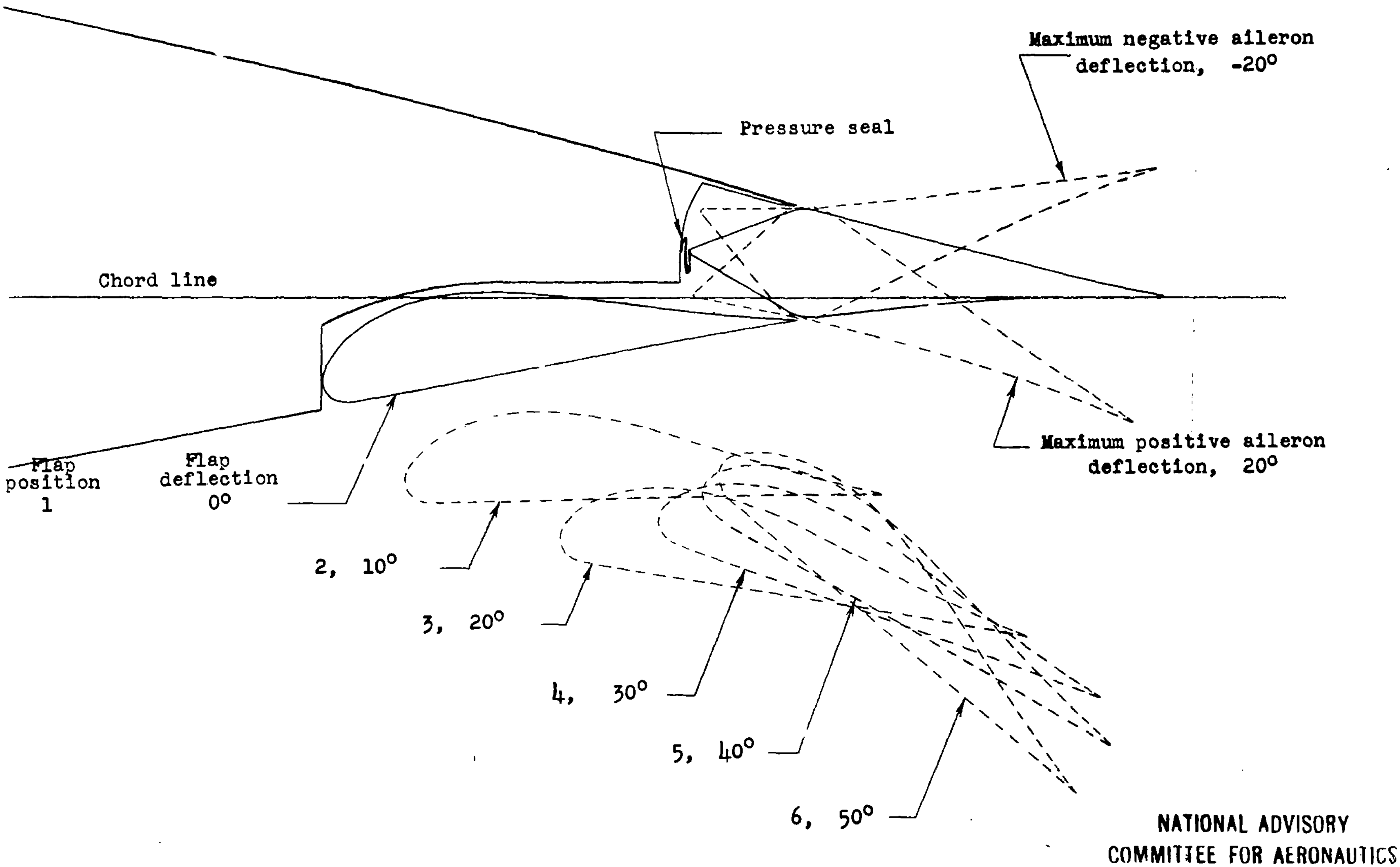

Figure 12.- Positions of balanced split flap and arrangement of internally balanced aileron on outboard wing section model of XB-36 airplane.

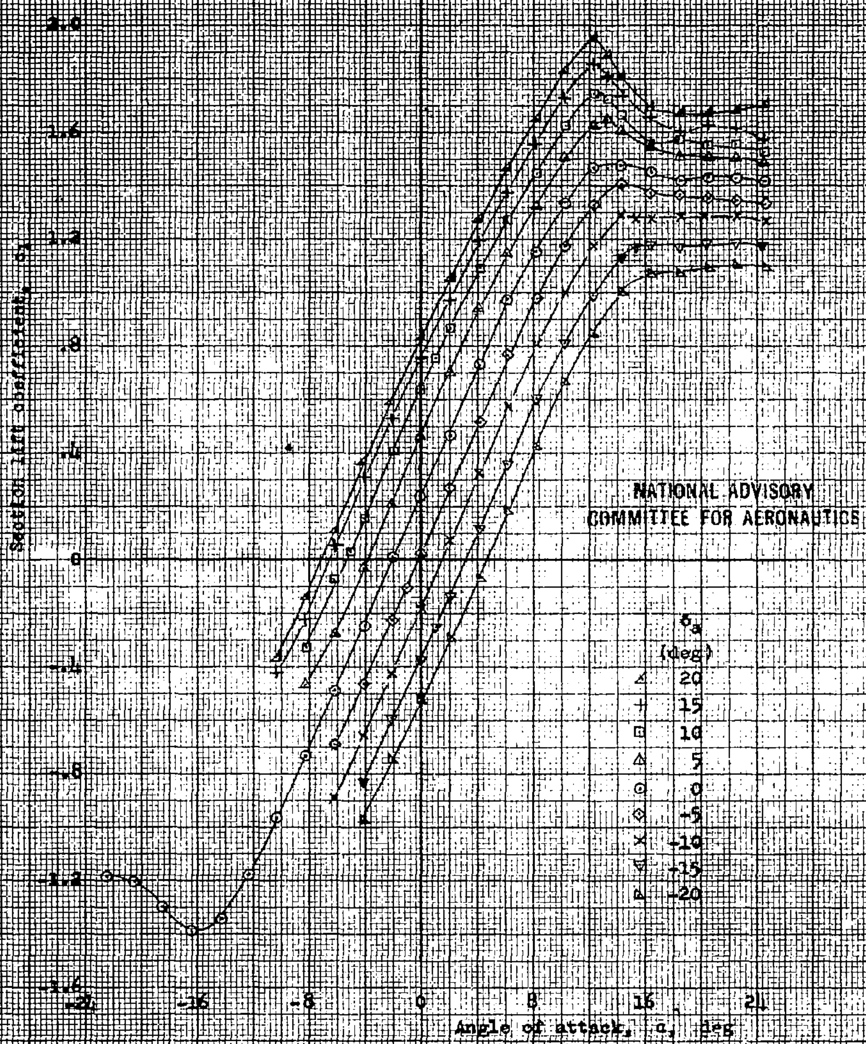

Figure 13.- Lift characteristics of outboard wing section model of XB-36 airplane with various aileron deflections. Flap position 1; R, 8×10^6.

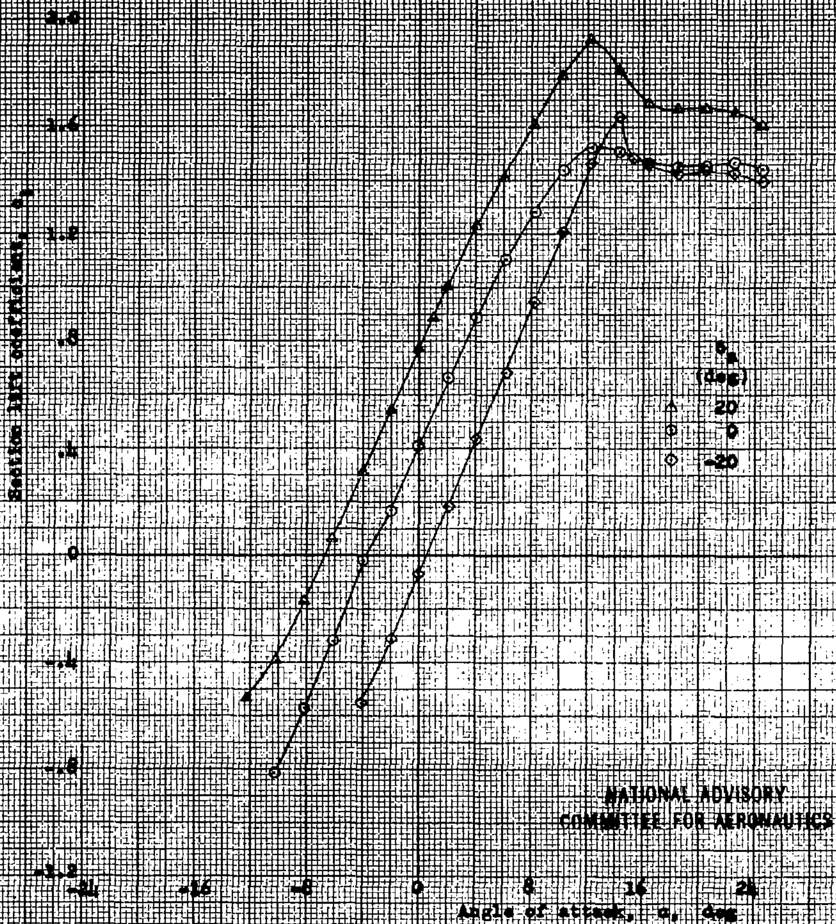

Figure 14.- Lift characteristics of outboard wing section model of XB-36 airplane with three aileron deflections. Flap position 2; R, 8 x 10^6.

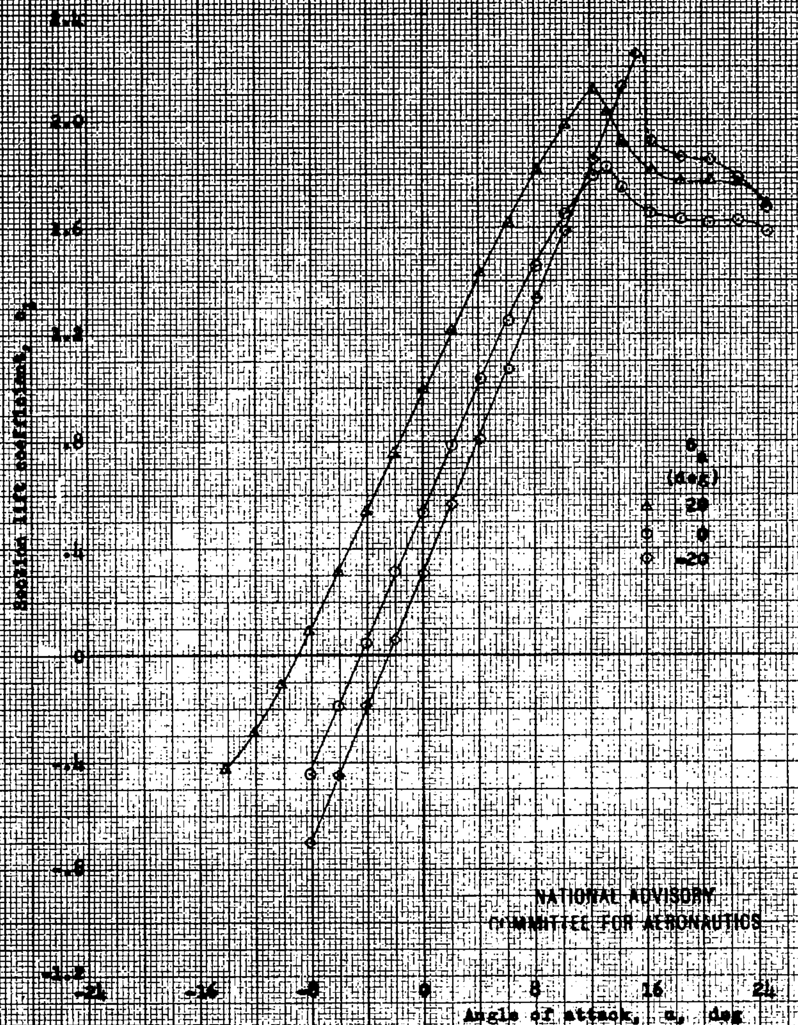

Figure 15.- Lift characteristics of outboard wing section model of XB-36 airplane with three aileron deflections. Flap position 3; R, 8 × 10^6.

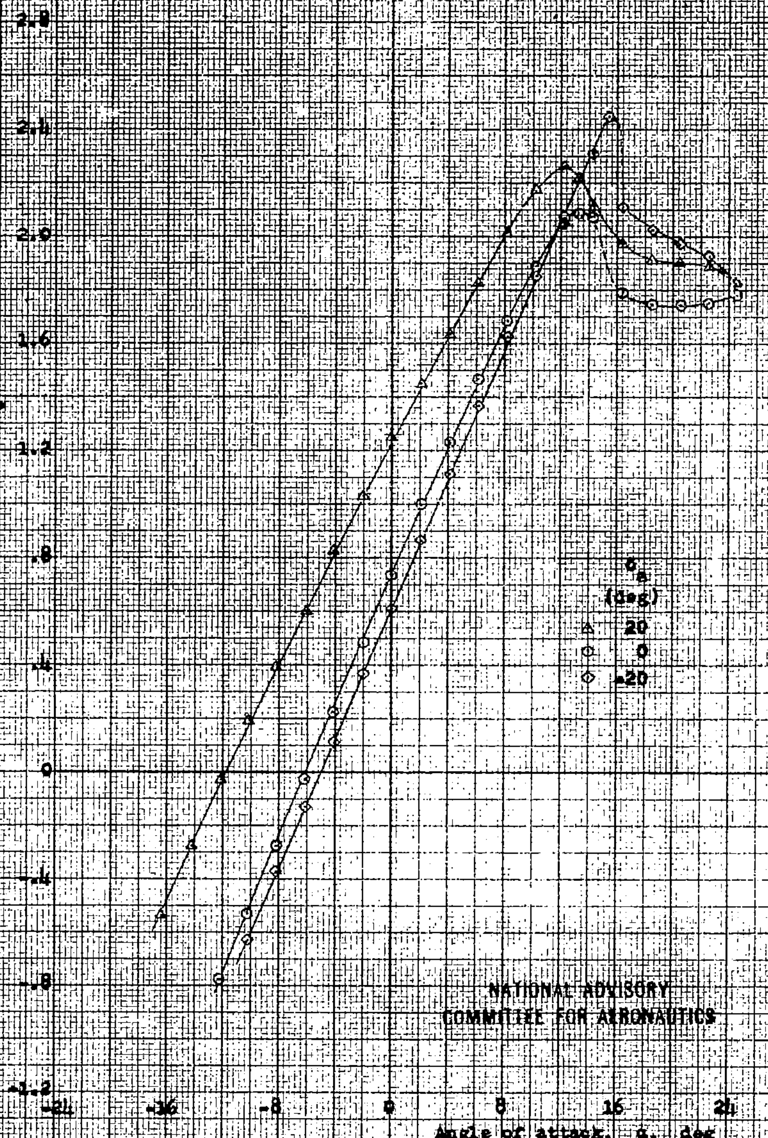

Figure 16.- Lift characteristics of outboard wing section model of XB-36 airplane with three aileron deflections. Flap position 4; R, 8 × 10^6.

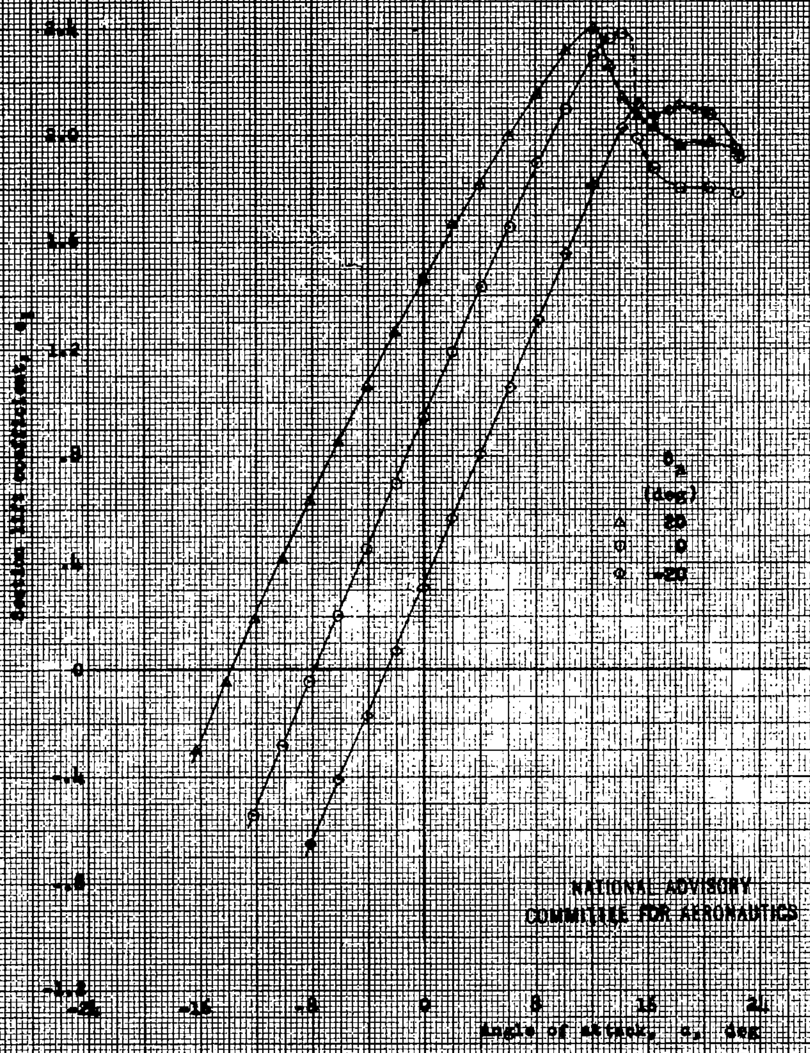

Figure 17.- Lift characteristics of outboard wing section model of XB-36 airplane with three aileron deflections. Flap position 5; R, 8 × 10^6.

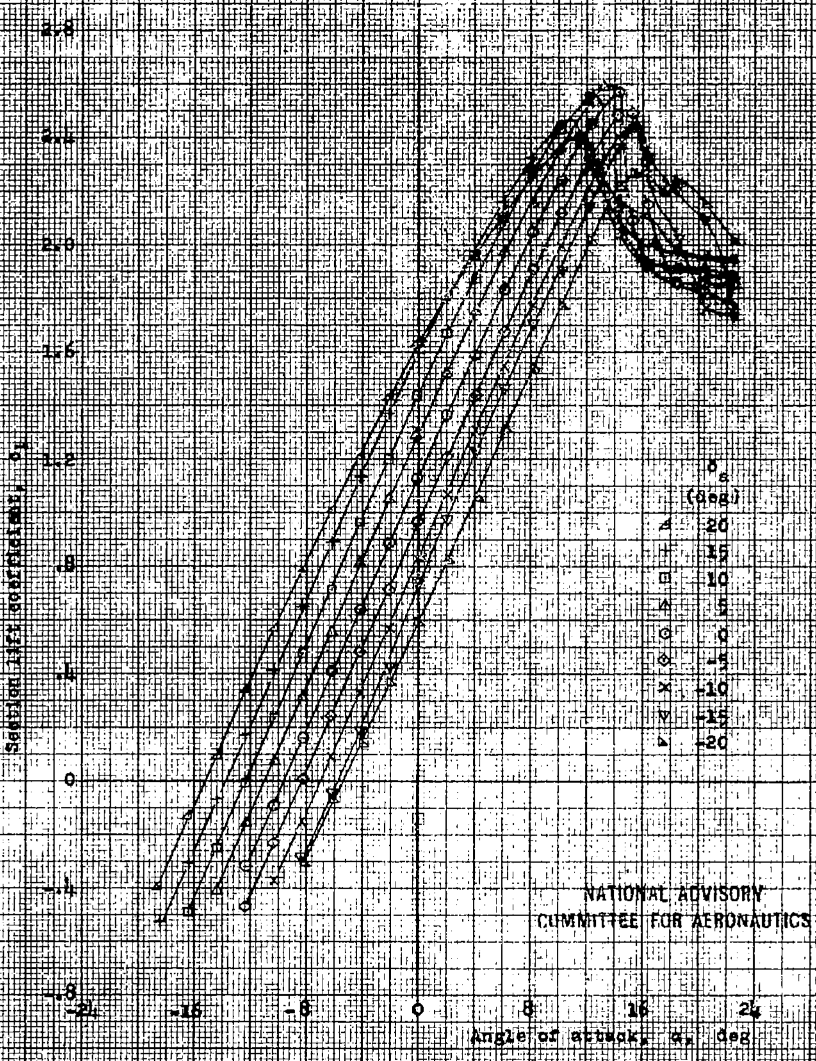

Figure 13.- Lift characteristics of outboard wing section model of XB-36 airplane with several aileron deflections. Flap position 6; R, 8×10^6.

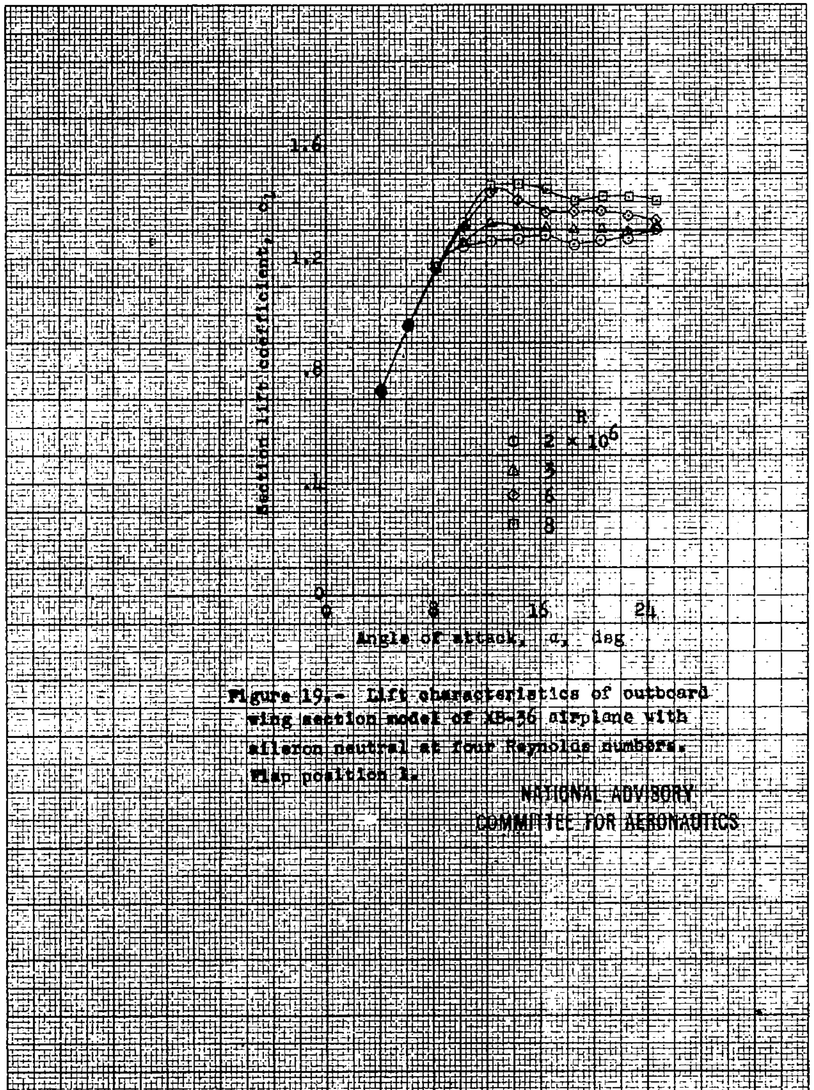

Figure 19.- Lift characteristics of outboard wing section model of XB-36 airplane with aileron neutral at four Reynolds numbers. Flap position 1.

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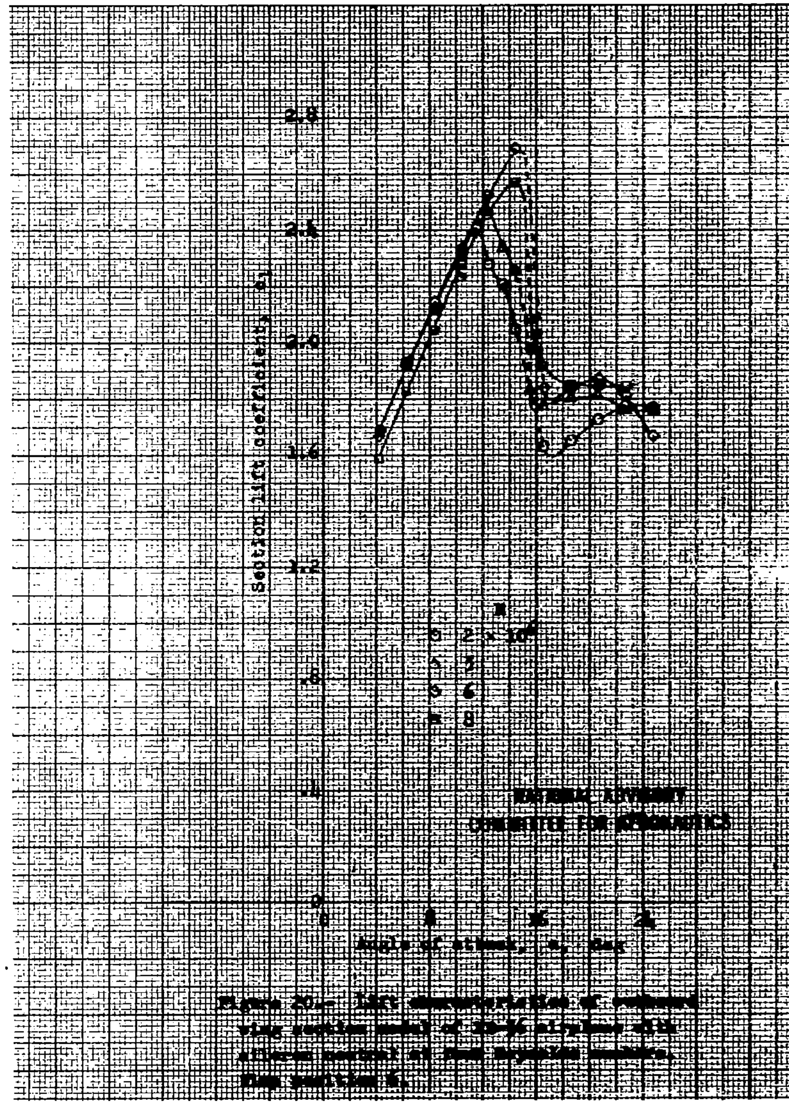

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Figure 20.- Lift characteristics of outboard wing section model of XB-36 airplane with aileron neutral at four Reynolds numbers. Flap position [illegible].

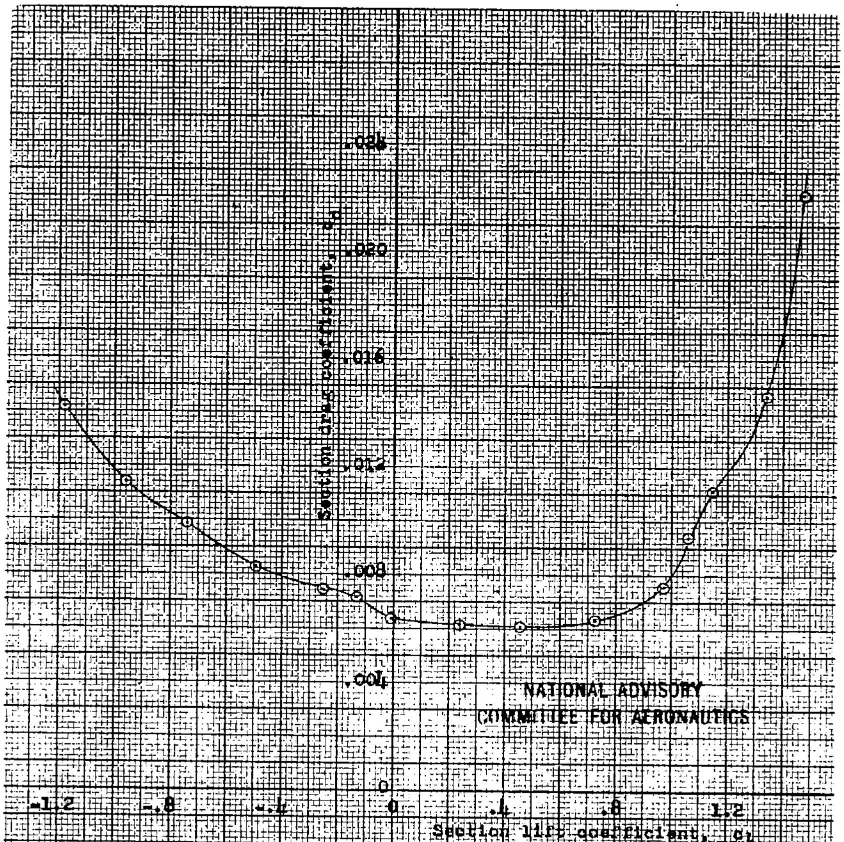

Figure 21.- Drag characteristics of outboard wing section model of XB-36 airplane with aileron neutral. Flap position 1; R, 8×10^6.

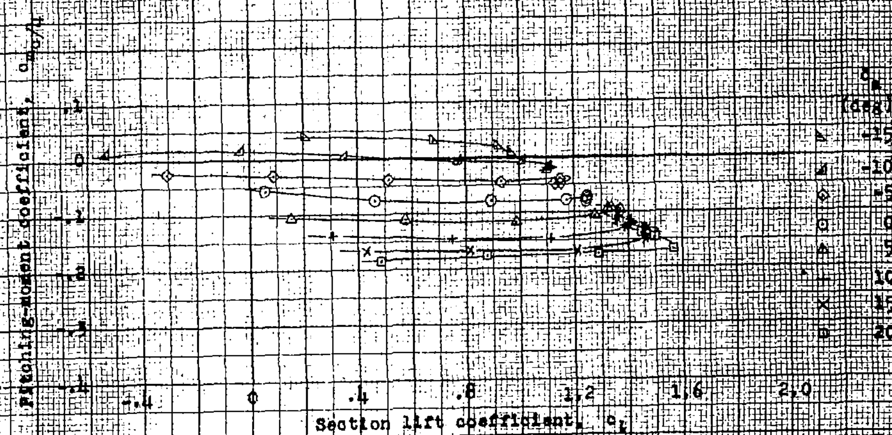

Figure 22.- Pitching-moment characteristics of outboard wing section model of XB-36 airplane with various aileron deflections. Flap position 1; R, 2×10^6 (approx.).

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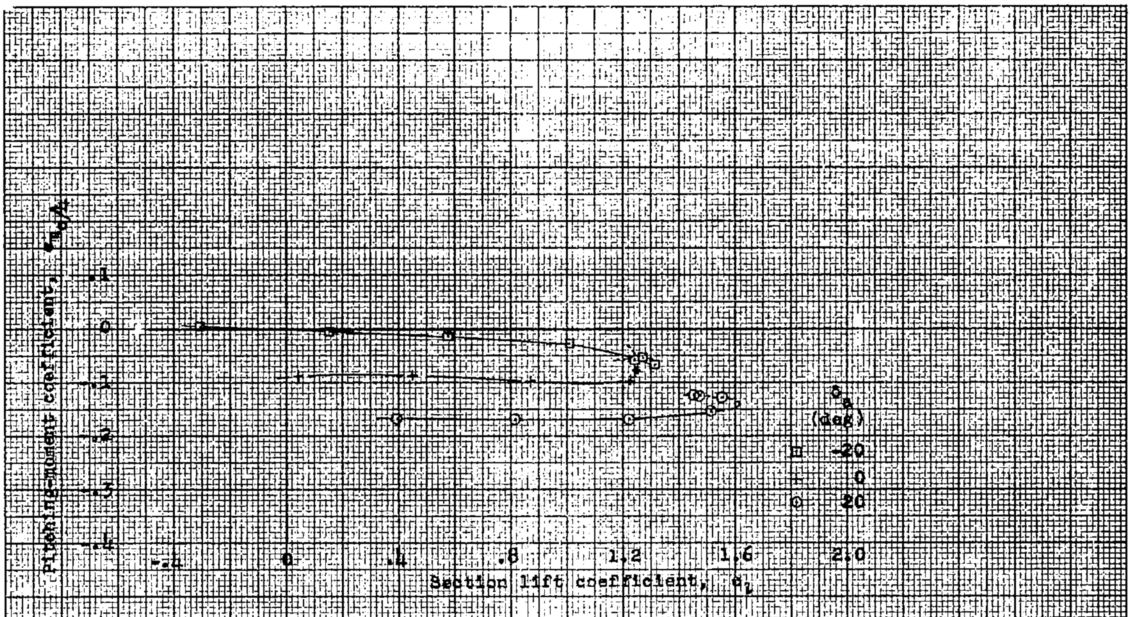

Figure 23.- Pitching-moment characteristics of outboard wing section model of XB-36 airplane with three aileron deflections. Flap position 2; R, 2 × 10[6] (approx.).

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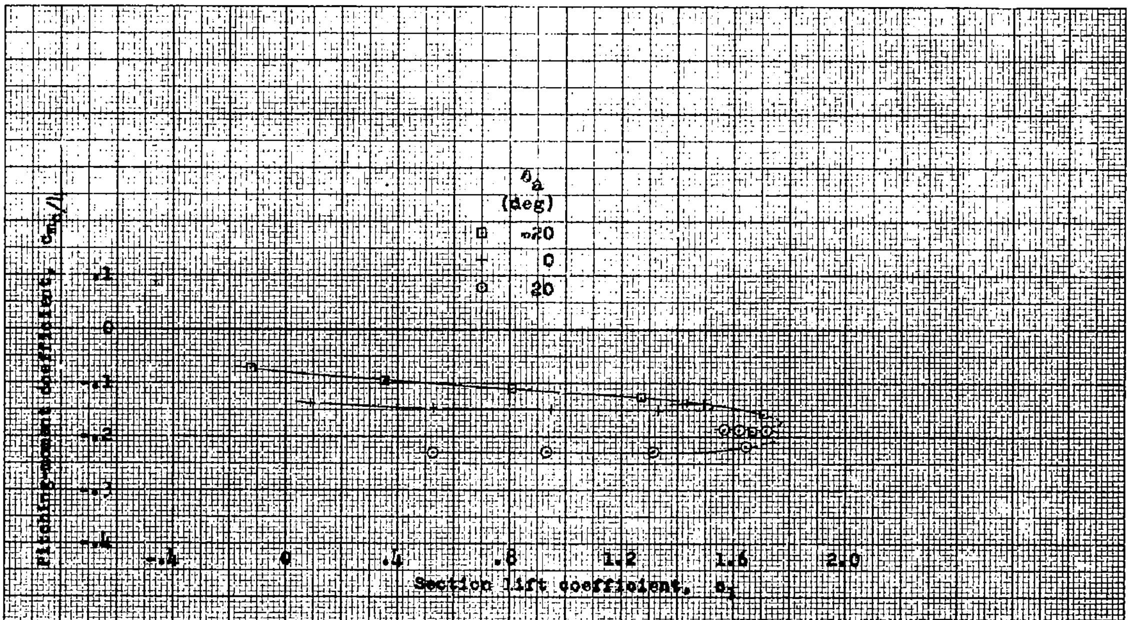

Figure 24.- Pitching-moment characteristics of outboard wing section model of XB-36 airplane with three aileron deflections. Flap position 3; R, 2 × 10[6] (approx.).

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Figure 25.- Pitching-moment characteristics of outboard wing section model of XB-36 airplane with three aileron deflections. Flap position 4; R, 2×10^6 (approx.).

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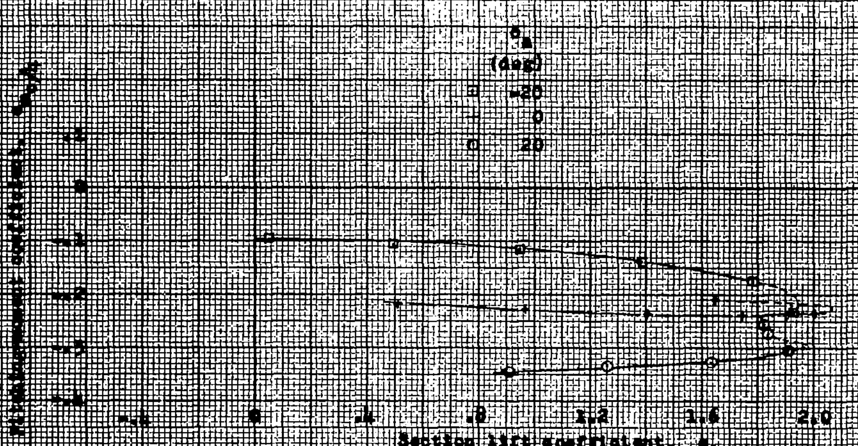

Figure 26.- Pitching-moment characteristics of outboard wing section model of XB-36 airplane with three aileron deflections. Flap position 5; R, 2×10^6 (approx.).

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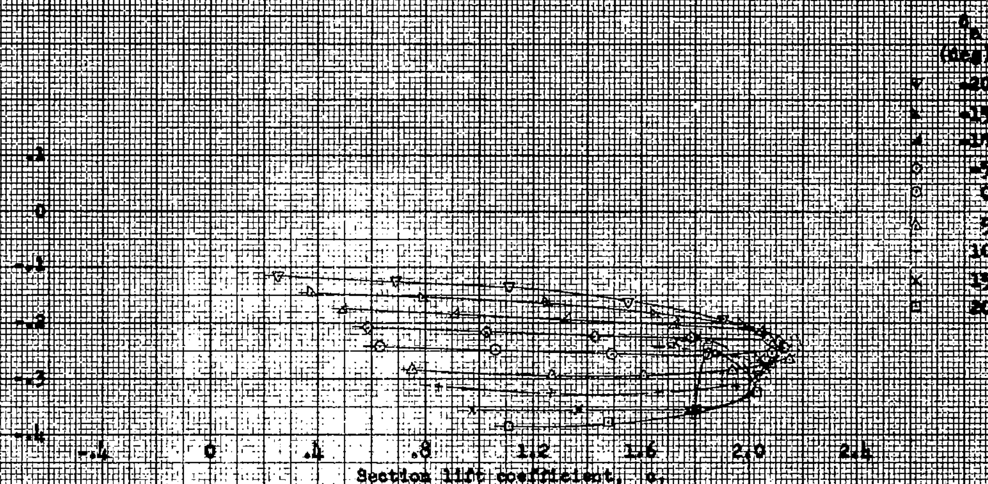

Figure 27.- Pitching-moment characteristics of outboard wing section model of XB-36 airplane with several aileron deflections. Flap position 6; R, 2×10^6 (approx.).

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